



The Problem

Loma Prieta and Northridge Were a Wake-Up Call

The Nightmares

In one nightmare, the Hayward fault – extending from San Pablo Bay to the Alameda County–Santa Clara County border – suddenly ruptures, generating a magnitude 7.3 earthquake.

- ◆ Over 155,000 housing units are made uninhabitable.
- ◆ Almost 360,000 people are forced from their homes.
- ◆ Over 110,000 people require publicly-provided shelter.

At the same time –

- ◆ The phone system is overwhelmed.
- ◆ Power outages are widespread.
- ◆ Water and sewer are out of service due to numerous pipe breaks.
- ◆ The transportation system is crippled by over 1,600 road closures.

In another nightmare, the Peninsula-Golden Gate segment of the San Andreas fault – extending from the Santa Cruz Mountains near Hwy. 17 to west of the Golden Gate Bridge – ruptures, generating a magnitude 7.3 earthquake and closing over 800 roads. Fewer homes and apartments are located nearby than in the Hayward earthquake.

- ◆ “Only” 110,000 housing units are made uninhabitable, including 66,000 in San Francisco.
- ◆ Almost 240,000 people are forced from their homes.
- ◆ Over 70,000 people require publicly-provided shelter.

This report is intended to provide information so that cities and counties can develop effective programs encouraging homeowners to retrofit and, thereby, prevent these nightmares. The focus of this report is on structural retrofitting, not on nonstructural measures (which include gas shut-off valves and strapping water heaters to walls).

OUR HOUSING WILL BE DECIMATED

The Number of Uninhabitable Homes Expected Is Huge and Extends Over the Entire Bay Area

The 1989 Loma Prieta earthquake caused a total of over 16,000 units to be uninhabitable throughout the Monterey and San Francisco Bay Areas (including almost 13,000 in the Bay Area). As shown in Table 1 below, ***thirteen*** of 18 potential Bay Area earthquakes analyzed are expected to have a far larger impact than the Loma Prieta earthquake. In fact, ***eight*** of these earthquakes will probably have a greater impact than the 1994 Northridge earthquake in the Los Angeles area, where over 46,000 housing units were made uninhabitable. ***Many Bay Area faults can generate earthquakes and every Bay Area county is significantly affected by at least two. Several of the larger earthquakes on longer faults will impact several counties.***

TABLE 1: Predicted Uninhabitable Units for Bay Area Counties and Selected Earthquake Scenarios

Earthquake Scenario	Alameda	Contra Costa	Marin	Napa	San Francisco	San Mateo	Santa Clara	Solano	Sonoma	TOTAL
Santa Cruz Mts.-San Andreas	1,968	159	297	0	11,781	223	1,277	2	3	15,710
Peninsula-Golden Gate San Andreas	4,243	224	1,516	3	66,094	22,915	15,364	11	43	110,413
Northern Golden Gate San Andreas	3,411	398	2,845	19	59,965	1,178	448	127	1,749	70,140
Entire Bay Area San Andreas	16,048	1,173	3,495	20	82,354	24,472	29,593	185	2,530	159,870
No. San Gregorio	3,104	238	1,176	4	38,306	9,040	589	12	45	52,514
So. Hayward	64,451	1,760	1,030	16	13,940	245	11,892	126	37	93,497
No. Hayward	43,132	7,686	1,653	19	11,464	210	303	128	74	64,669
N + S Hayward	88,265	10,102	2,125	36	37,670	1,616	14,273	1,046	559	155,692
Rodgers Creek	3,688	1,418	1,549	53	11,460	151	100	1,148	13,988	33,555
Rodgers Creek-No. Hayward	49,284	9,786	2,691	713	29,758	363	402	1,386	14,115	108,498
So. Maacama	325	17	27	22	1,986	11	11	15	825	3,239
West Napa	1,382	286	27	4,284	2,011	15	29	1,668	126	9,828
Concord-Green Valley	3,511	11,363	29	1,307	3,191	76	325	2,868	37	22,707
No. Calaveras	7,836	3,509	27	18	3,191	78	4,882	181	6	19,728
Central Calaveras	3,037	75	27	3	3,191	182	10,145	13	4	16,677
Mt. Diablo	6,128	4,868	751	3	10,489	23	109	17	4	22,392
Greenville	3,114	5,175	27	30	2,376	22	258	212	33	11,247
Monte Vista	323	5	16	1	2,429	2,392	27,223	2	2	32,393

TABLE NOTES – This table is based on ABAG's modeling of uninhabitable housing units in future earthquake scenarios (*Shaken Awake!*, Perkins and others, 1996). This modeling is based on an extensive statistical analysis of the housing damage which occurred as a result of the 1989 Loma Prieta and 1994 Northridge earthquakes. However, the expected percentage of pre-1940 single-family homes rendered uninhabitable used to generate this table is larger than published in 1996. New data on lack of retrofitting and reasons for low damage in the Northridge earthquake caused ABAG to increase the uninhabitable percentages used to create this table for pre-1940 single-family homes to 19% and 25% for MMI IX and X, respectively.

Note that several fault segments listed above have new segment end points or were not included in the 1996 report. They are included in this table to reflect ground

shaking information published by USGS in 1999. The Santa Cruz Mts.-San Andreas is similar, but not identical, to the fault causing the Loma Prieta earthquake. The Monte Vista and West Napa faults have been added to the faults analyzed by USGS to illustrate the impact of an earthquake in these areas. The Maacama fault could impact the North Bay, but too little was known about the fault for the USGS to issue probabilities for it in 1999. It, too, has been added to illustrate possible damage. On the other hand, the Southern Calaveras, the Southern San Gregorio, and the northern North Coast-San Andreas faults are outside of the Bay Area. The Bay Area impacts of earthquakes on these fault segments are dwarfed by their Bay Area segments so they are not included. Additional information on earthquakes and housing is available in *Shaken Awake!* and on the ABAG Earthquake Program Internet site at <http://quake.abag.ca.gov>.

shaking

Map HERE showing Bay Area Faults and Fault Segments

PEOPLE WILL NEED TO BE TEMPORARILY SHELTERED

And the Nightmare Doesn't End When the Ground Stops Shaking

During the first three to six weeks following a major earthquake, the American Red Cross, as well as local governments and other organizations, struggle to operate hundreds of emergency shelters for the displaced and to feed many more. Shelters, typically set up for a short period of time, will need to remain open for months, partially because of the Bay Area's low vacancy rate and high occupancy levels. Finding housing is a major challenge in the Bay Area even before an earthquake strikes!

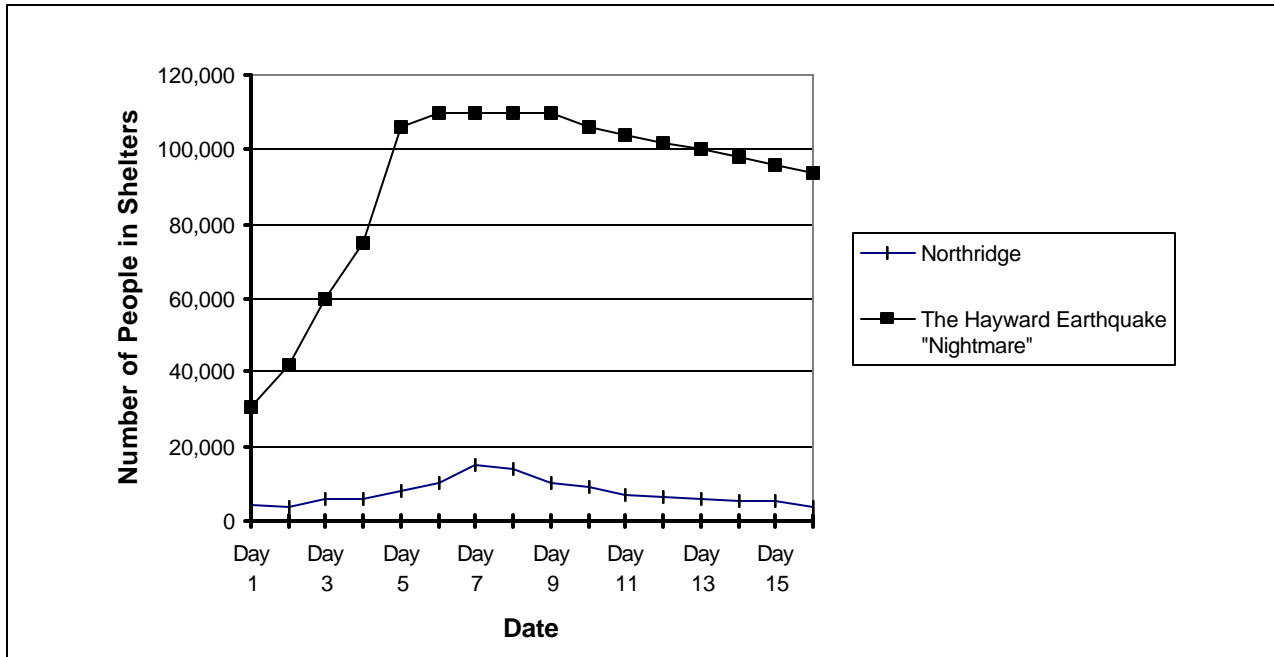


photo source – American Red Cross

The response needs for several of these scenario earthquakes will exceed anything ever experienced in this country. The American Red Cross effort to shelter, feed, and provide emergency assistance after the Northridge earthquake cost \$7.2 million. The cost of the Red Cross effort after Hurricane Andrew was \$13 million. The cost for the Hayward scenario “nightmare” could easily exceed either of these numbers by a factor of ten. The response will stress the resources of government and nongovernment response agencies.

And when these agencies complete their emergency assistance, cities and counties of the impacted area continue to pick up the pieces of intermediate and long-term housing shortages for **years**.

Long-term sheltering can have severe secondary impacts, as well. As illustrated in both southern California after the Northridge earthquake and in Kobe, Japan, the damaged neighborhoods can be socially decimated – with large increases in substance abuse, suicide rates, and violence.

OUR HOUSING WILL NEED TO BE REPAIRED AND REBUILT

The Process Takes Years

The repair, rebuilding and recovery process begins when the ground stops shaking. In general, mobile homes and single-family homes are repaired or rebuilt far more quickly than multifamily housing.

The rate of reconstruction of the housing stock depends on several local factors – incentive, technology, financing, regulation, available space, self help, and luck.

*Prof. Mary Comerio
Professor of Architecture
University of California, Berkeley*

The Bigger the Earthquake, the Longer the Recovery – the Lesson of Mobile Homes

However, the larger the earthquake, the slower the recovery process. Repairs that might be expected to take a few days to a few weeks after a moderate earthquake, can take months or years in a larger earthquake. For example, in the Northridge earthquake, approximately 4,600 mobile homes were either destroyed or so badly damaged that they were uninhabitable. Although the California Housing and Community Development Department staff estimated that it would take “a couple of weeks” for the units to be repaired and habitable, this estimate is not measured from the moment of the earthquake itself. Instead, it is measured from the time a contractor is available to repair a particular mobile home park. After Northridge, the State also made repair funds available to mobile home owners. However, the entire process of reoccupying units in these parks took an entire year.

The 7-Year Recovery of Watsonville

Watsonville, a small town in Santa Cruz County, contained slightly more than 9,900 housing units when the Loma Prieta earthquake struck. The vacancy rate was only 1.7% for rental units. A total of 129 single-family homes, 119 small multifamily buildings containing 431 units, and 266 mobile homes were severely damaged and vacated due to the earthquake, representing 8.34% of the housing stock. The mobile homes were repaired within one month. Approximately 70% of both the single-family and multifamily buildings were repaired within one year. After two years, 96% of the single-family homes, but only 82% of the multifamily buildings, were repaired. The complete recovery took almost seven years!

The Need for Assistance Is Huge – the City of Los Angeles Story

The repair bills for residential buildings damaged by the Northridge earthquake were unprecedented. The estimate of damage to residential buildings was \$12.7 billion. ***Approximately 98% of the rebuilding and repairs had been completed within five years of that earthquake, but not without a large influx of funding.*** A large proportion (approximately \$8 billion) of these losses was covered by earthquake insurance. The City of Los Angeles financed and supported the repair and rehabilitation of over 13,000 housing units with \$314 million in loans. The U.S. Department of Housing and Urban Development provided the City with \$360 million for these loans and other assistance. In addition, HUD provided rental assistance for low-income families displaced. ***It is very unlikely that insurance company and federal government resources and assistance will be adequate for our Bay Area nightmare.***

PROBLEMS VARY BY BUILDING TYPE



source – J. Perkins

Single-Family Homes

will be responsible for 9% of the uninhabitable housing units following the Hayward scenario “nightmare.”



Older (usually pre-World War II) houses that are not bolted to their foundations or lack bracing of walls enclosing a crawl space (the cripple wall) accounted for over 2,800 of the 16,000 housing units made uninhabitable by the Loma Prieta earthquake. However, they accounted for only 439 of the 48,000 uninhabitable units resulting from the Northridge earthquake due to (1) the relatively newer housing stock in the San Fernando Valley, (2) the large number of homes built on concrete slab foundations which, therefore, do not have cripple walls, and (3) the large number of homes that had been retrofitted following the 1971 San Fernando earthquake, which impacted much of the same area. ***We will not be as lucky when an earthquake strikes the Bay Area.*** Single-family homes can be heavily damaged even if residents can continue to live in them. Pre-World War II homes are expected to account for over 11,000 of the almost 156,000 uninhabitable housing units following a 7.1 earthquake on the Hayward fault. An additional 2,200 post-World War II homes are also expected to be uninhabitable; homes with living area over a garage, on hillsides, or lacking adequate cripple wall bracing are most vulnerable.

Structural retrofit of older houses typically includes a combination of adding anchor bolts to prevent sliding off their foundations and adding plywood sheathing along portions of the cripple walls to prevent a collapse of those walls. In some cases, a design professional should be consulted because existing foundations need to be strengthened, or because two-or-three-story houses need stronger walls at the sides of garage door openings.



source – K. Steinbrugge

Mobile Homes

will be responsible for 7% of the uninhabitable housing units following the Hayward scenario “nightmare.”



Mobile homes installed prior to 1995 that are not well tied to their foundations are prone to shifting off their supports in damaging earthquakes. Mobile homes accounted for only a couple of hundred of the uninhabitable units resulting from the Loma Prieta earthquake. However, they accounted for almost 4,600 of the uninhabitable units resulting from the Northridge earthquake. Mobile homes are expected to account for over 11,000 of the almost 156,000 uninhabitable units resulting from an earthquake on the entire Hayward fault. These units house a disproportionate share of the elderly and poor, particularly in the North and South Bay.

Three common methods can ensure that mobile homes are structurally safe, that is, that they are properly tied to their foundations (in the order of their effectiveness and cost):

- ◆ Owners can consult a design professional and install a conventional foundation similar to that for a wood-frame home;
- ◆ For new homes or existing homes being relocated, they can install an Engineered Tiedown System using Standard Plan Approvals; or
- ◆ For existing homes, they can install a Certified Earthquake Resisting Bracing System.

Lists of manufacturers for Engineered Tiedown Systems and Certified Earthquake Resisting Bracing Systems are available from the California Dept. of Housing and Community Development. (See the section on ***Additional Information Sources*** at the end of this report.)



source – J. Perkins

Wood-Frame Apartments

will be responsible for 66% of the uninhabitable housing following the Hayward scenario “nightmare.”



Multifamily wood-frame residential buildings, particularly with all or part of the first floor used for parking (“soft-story” buildings) are a huge problem in earthquakes. They were responsible for 7,700 of the 16,000 housing units rendered uninhabitable by the Loma Prieta earthquake and over 34,000 of the housing units rendered uninhabitable by the Northridge earthquake. The potential for deaths in these buildings was driven home when 16 people were killed in the Northridge Meadows apartment complex. Wood-frame multifamily units are expected to account for 103,000 of the projected 156,000 uninhabitable housing units from an earthquake on the entire Hayward fault. These same units also are expected to be the source of a disproportionate share of the public shelter population because they tend to be occupied by people with limited resources – the very poor, the very old, and the very young.

The structural retrofitting for apartments is more complex than for homes. The retrofit should involve a specific solution designed by a structural engineer or other design professional with past experience in this type of work. Retrofitting multi-family buildings with large openings for parking involves adding bracing elements, like steel frames or shear walls at the lowest story level, and tying this bracing into the floor above that level. In taller buildings, some upper story walls may also need strengthening. Because a building’s height, shape and existing construction materials may vary, these factors can require additional retrofit measures to prevent collapse.



source – H. Degenkolb

Unreinforced Masonry Buildings

will be responsible for 8% of the uninhabitable housing following the Hayward scenario “nightmare.”



Damage to a variety of other non-wood frame multifamily buildings will be responsible for the remaining 10% of the uninhabitable housing units in the Hayward “nightmare.”

Unreinforced masonry buildings were responsible for almost 2,000 of the uninhabitable units resulting from the Loma Prieta earthquake, even though they were only 1% of the Bay Area’s housing stock and none of these buildings were subjected to violent shaking (intensity IX or higher) in that earthquake. They accounted for 3,100 of the uninhabitable units resulting from the Northridge earthquake. This number would have been higher except for the aggressive program of the City of Los Angeles to retrofit these structures for life safety. Many of these buildings in other cities still pose a serious life-safety concern. Unreinforced masonry buildings are expected to account for close to 13,000 of the almost 156,000 uninhabitable units resulting from a magnitude 7.1 Hayward fault earthquake. Again, however, these units house a disproportionate share of the poor, particularly in San Francisco.

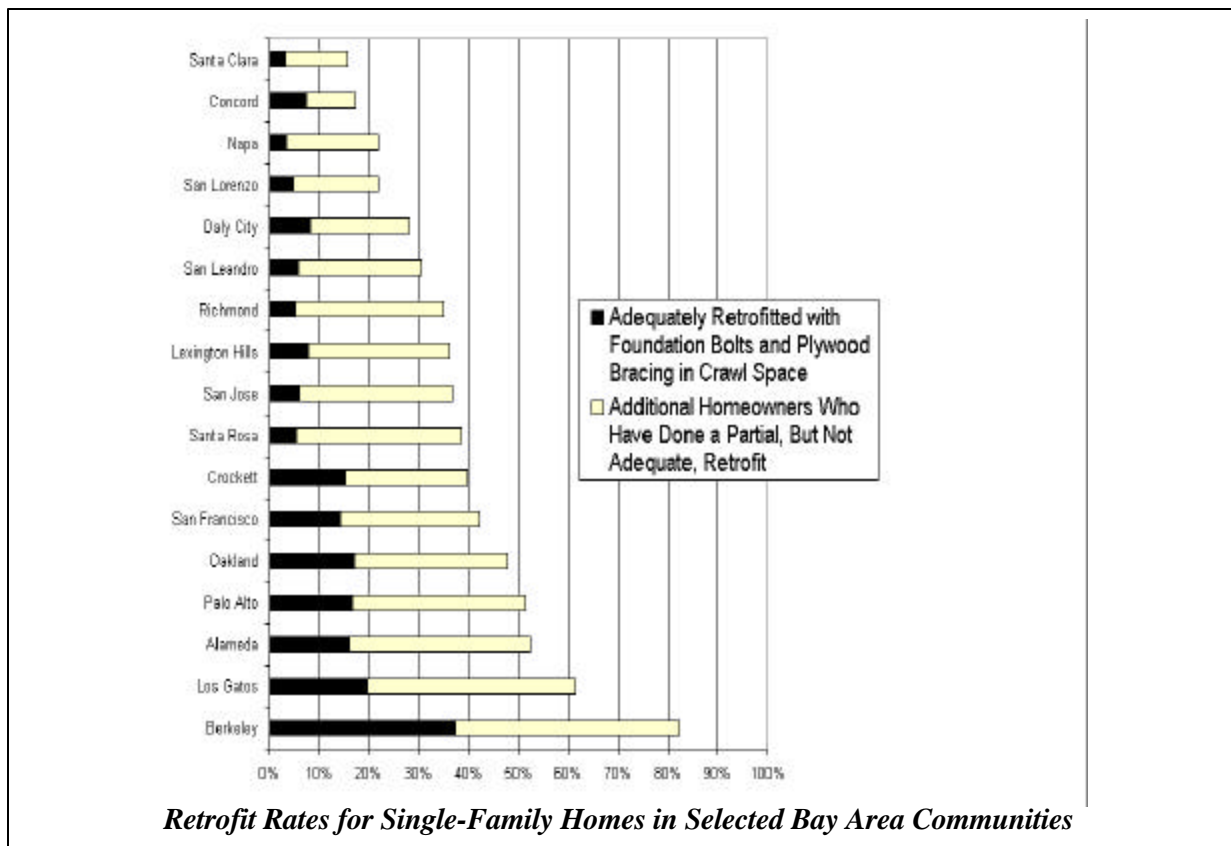
As with apartment buildings, the retrofit for unreinforced masonry buildings should be designed by a structural engineer or other qualified design professional. Structurally retrofitting unreinforced masonry buildings typically includes bracing parapets and adding anchors at each upper floor level and the roof to keep walls from collapsing. Some buildings may need added sheathing on the roof or floors; in taller buildings, some of the masonry walls may need to be strengthened with spray-applied concrete. Adding steel frames at storefront openings is also a common retrofit method.

OWNERS COULD BE RETROFITTING, BUT AREN'T

Few Owners of Single-Family Homes Are Retrofitting

Although we can work to be more effective in helping people cope with their losses following an earthquake, it also makes sense to reduce losses. The best way to do this is to retrofit our housing stock so that it is less likely to be damaged to the extent that people must vacate their homes.

Most homeowners are not retrofitting – and those that retrofit are not doing all the work needed to significantly change the likelihood that the homes will be habitable following future earthquakes. This conclusion is based on two sources of information. First, in the summer of 1998, ABAG conducted a survey of single-family homeowners in 17 communities to find out why they were or were not retrofitting. Second, in 1998, we worked with the American Society of Home Inspectors (ASHI) to gather information on retrofit rates for single-family housing in the East Bay.



Fewer Owners of Large Apartment Buildings Are Retrofitting

Retrofit rates for multifamily buildings with more than four units are significantly lower than for single-family homes or small multifamily buildings of 2-4 units. However, the retrofit rate in Berkeley is higher than in neighboring Oakland due, in part, to that City's property transfer tax rebate program which serves as a significant financial incentive for retrofit. These conclusions are based on ABAG's survey of multifamily residential owners in Berkeley and Oakland in the summer of 1999, and data collected on multifamily housing for ABAG by ASHI in 1998.